# AN ANALYSIS OF THE INTERNATIONAL GREAT LAKES LEVELS BOARD REPORT ON REGULATION OF GREAT LAKES WATER LEVELS

## SUMMARY REPORT

Water Resources Management Workshop
and
Lake Superior Project

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University of Wisconsin Madison

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September 1976





WISCONSIN COASTAL MANAGEMENT

# AN ANALYSIS OF THE INTERNATIONAL GREAT LAKES LEVELS BOARD REPORT ON REGULATION OF GREAT LAKES WATER LEVELS

## SUMMARY

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Rockefeller Lake Superior Project
Water Resources Management Workshop
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Other working papers in this series include the following:

RF Monograph 76-01
IES Working Paper 27 — Hydrology

RF Monograph 76-02
IES Working Paper 28 — Navigation

RF Monograph 76-03
IES Working Paper 29 — Shore Property and Recreation

RF Monograph 76-04
IES Working Paper 30 — Wetlands, Fisheries and Water Quality

RF Monograph 76-05
IES Working Paper 31 — Institutions

These papers are based upon research completed in December 1975.

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# FINDINGS AND CONCLUSIONS

1. All of the regulation plans proposed by the International Great Lakes Levels Board (IGLLB) can exercise only limited control over the fluctuation of water levels on the Great Lakes. Natural factors such as climate and the configuration of connecting channels exert, by far, the major influence.

2. Given the existing knowledge about the prediction of lake levels and the economic effects of regulation, the IGLLB evaluation of alternative regulation plans is thorough. Because of the great uncertainty associated with the Levels Board's hydrologic and economic projections and the failure to include costs of compensating those injured by a change in regulation plans, the estimates of benefits are highly unreliable as a basis for selecting a plan. An indication of the possible ranges of benefits under various regulation plans would be more useful than simply the average annual benefit figures given by the Levels Board.

3. The International Joint Commission (IJC) has stated that compensation of those damaged will be a necessary component of the proposed regulation plans. The feasibility of determining reasonably precise compensation is questionable because the data are inadequate to separate man-induced damages from natural damage and because of the large administrative costs. Once determined, the costs of compensation, both indemnity and administrative expenses, should be included in selecting a regulation plan.

4. The climate of the 1900 to 1967 base period used in the Levels Board study poorly represents longer term climatic characteristics of the past several centuries. Several studies of climate subsequent to the Levels Board analysis indicate that the climate conditions which dominated the first half of the twentieth century which appears to have favored low net basin supplies do not exist today. Because there is a reasonable probability that this change in climate will persist for two or three decades, the net basin supplies used in the Levels Board analysis would be lower than those which have a reasonable chance of occurring during the next few decades.

5. Lake Superior is particularly vulnerable to the proposed management plans because the plans recommended by the IGLLB use Lake Superior as a reservoir to reduce the range of lake level fluctuation on the more developed lower lakes.

6. Because the information on shore damages is scarce and general, the IGLLB method provides at best a very general indication of possible losses under various regulation plans and not an accurate quantitative analysis. For example, all damages are based on a 1951-52 damages survey and on an assumed relationship between lake level and damage. Although the Levels Board study estimated damages to structures, the value of undeveloped lands lost, and effects on recreation beaches, inadequate consideration was given to nonmonetary values such as impacts on wetlands and water quality.

7. In the 1964 reference to the IJC, Canada and the United States did not authorize the commission to consider regulation techniques which are not currently under IJC authority. The Levels Board subsequently did not address management of the Long Lake-Ogoki and Chicago diversions in conjunction with lake level regulations plans.

8. The available information on how lake level fluctuation affects wetlands, fisheries, and water quality is too incomplete to measure the impact of the regulation plans. Because public values of environmental quality are not readily assessed economically, the Levels Board did not adequately consider how environmental quality trades off with other interests. It is also difficult to separate the consequences of regulation from other human perturbations such as filling and dredging of wetlands. One may assume that environmental quality will best be preserved by maintaining the natural regime of level fluctuation.

9. Because the Levels Board includes fixed costs in its calculations of navigation benefits from regulation plans, these benefits may be overstated by as much as 40%. Furthermore, although Lake Superior levels appear to be an important factor with respect to navigation interests, lock sizes plus dock capacity and location are the major constraints on vessel size and capacity. Commercial navigation on the Great Lakes is important to the economy of Wisconsin ports and should be considered in the development of a state position toward regulation.

10. State and local interests were excluded for all practical purposes from the Levels Board's development of regulation plans. The IGLLB asked Wisconsin's Public Service Commission and former Department of Conservation only to provide information, not to participate in recommending regulation plans. The states should be involved in the policy deliberations and activities of the International Joint Commission concerning lake level regulation which affects the states.

11. All of the regulation plans studied by the University team provide net benefits to Great Lakes interests overall, but the impact of these plans on Wisconsin varies:

    (a) Plan SO-901 would raise the level of Lake Superior for approximately 60% of the months during the period 1900-1973 relative to the standardized base situation. Lake Superior shore interests therefore suffer net losses. The Levels Board's analysis using generalized loss curves also suggests that, in light of the probability of higher net basin supplies during the next few decades, Lake Superior shore losses could exceed Lake Michigan shore benefits.

    (b) Plans SO-901 Mod 7 and Mod 8 reduce Lake Superior mean levels by 0.4 to 0.7 feet and increase the variations of levels on that lake while reducing levels variation on Lakes Michigan and Huron. Generalized analyses by the IGLLB indicate that these plans provide benefits to both Lake Michigan and Lake Superior shore interests, but more careful study of the possible range of benefits and losses under these plans is necessary. Dredging costs to accommodate the lower levels significantly reduce the benefits of these plans. Dredge spoil disposal and increased variability of Lake Superior levels may also create environmental hazards.

(c) Plans SEO-42P and SEO-17P increase the outflow capacity from Lake Erie and utilize the same rule for Lake Superior outflow as Plan SO-901. Although Lake Michigan and Lake Superior levels are changed only slightly from those under Plan SO-901 (less than 2 inches difference in any month), the Levels Board analysis indicates net benefits for both Lake Michigan and Lake Superior shore interests. Further study of the possible range of benefits under these plans is necessary.

12. The University analysis is not intended to confirm or disprove the Levels Board report. The time, manpower and funding available were not sufficient for such an undertaking. Rather the report assists the development of a state perspective of this issue, and it points out that there are alternative methods which may be used to study lake level related problems. In some cases, these alternative methods confirm the Levels Board findings, and in other cases they suggest impacts different from those which the Levels Board indicates. These alternative methods led to the group's next and most important finding: *While the Levels Board methodology is careful and consistent, there is considerable uncertainty associated with the Levels Board's numerical estimates of benefits associated with various regulation plans.* For example, the evaluation of Plan SEO-17P relative to the Basis-of-Comparison suggests that the benefits of regulating the Great Lakes as a system with additional control at the outlet of Lake Erie are greater than those achieved when Lake Superior outflows are regulated only according to Lake Superior levels. It is not clear however that the benefits of Plans SEO-17P exceed the costs of implementing it. These costs include compensation of those damaged, and construction of a canal across Squaw Island and installation of heating cables on the gates at Sault Ste. Marie. Even though the construction and installation costs are relatively small, the benefits are also small and include considerable uncertainty. The administrative costs of compensation are presently unknown, but these costs could be considerable if erosion losses are to be compensated. Implementation of Plan SEO-17P could be more costly than continuing use of the 1955 Modified Rule of 1949.

# I. INTRODUCTION

## A. Scope and Purpose

This study analyzes the report Regulation of Great Lakes Water Levels prepared by the International Great Lakes Levels Board (IGLLB) for the International Joint Commission (IJC), a United States and Canadian commission created under the Boundary Waters Treaty of 1909. Specifically, this study addresses the following appendices of the Levels Board report:

A. Hydrology and Hydraulics
B. Lake Regulation
C. Shore Property
D. Fish, Wildlife and Recreation
E. Commercial Navigation.

This report evaluates methodologies used in the Levels Board report and assesses the impact of alternative regulation plans on Wisconsin. The purpose of this report is to provide a series of five working papers and a summary to be used by the state of Wisconsin in framing a response to the IJC regarding Great Lakes water level regulation. These working papers also will serve as general references to assist in coordination of state activities with the Great Lakes Basin Commission (a federal-state planning and coordinating body) or with other federal agencies.

These working papers represent a joint effort of a 1975 Water Resources Management Program Workshop and the Lake Superior Project at the University of Wisconsin-Madison. Partial funding for this effort has been provided through Wisconsin's Coastal Zone Management Development Program and the Wisconsin Department of Natural Resources provided important staff and administrative support. Other state and federal agencies (most notably the U.S. Army Corps of Engineers), faculty at the University and elsewhere, and citizen groups have provided valuable assistance in the completion of this analysis.

## B. Background

The Great Lakes are a naturally well-regulated system due to their large surface area and the stability of the outflows from the lakes. In order to improve benefits to such interests as navigation, hydroelectric power and shore property, the United States and Canada have installed regulatory works. For example, Lake Superior outflows have been completely regulated since 1921 and Lake Ontario outflows have been regulated since 1958. There are also four major diversions. The Long Lake and the Ogoki diversions bring water from the Albany River Basin in Canada into Lake Superior. Water from Lake Michigan is pumped through the Chicago Sanitary and Ship Canal, and finally the Welland Ship Canal diverts water from Lake Erie to Lake Ontario.

The regulation rules for control of outflows from Lake Superior and Lake Ontario have been changed a number of times as knowledge of Great Lakes hydrology has been improved and economic interests have evolved. For example, the rule for Lake Superior has been changed four times (1941, 1949, 1955, and 1973), and the Lake Ontario rule has been changed twice (1962 and 1963). In addition, deviations from the operating rules have been authorized during periods of extremely high or low net basin supplies. As one considers the impact of adopting a new operating rule, one must realize that any particular rule is unlikely to remain in effect more than twenty years.

On October 7, 1964, as a result of widespread concern about extremely low water levels, Canada and the United States submitted a reference to the International Joint Commission requesting the commission to study those factors which affect water level fluctuation and to determine the practicability of further action to alleviate the problems associated with such fluctuation. Under this reference the International Great Lakes Levels Board was established on December 2, 1964, composed of a member from each of the following agencies: U.S. Army Corps of Engineers (Corps), U.S. Department of Transportation, U.S. Department of the Interior, and the Department of Public Works, Department of Environment and Ministry of Transport in Canada. The Levels Board set up a working committee to collect data and organize necessary studies. The working committee then established subcommittees to investigate major problem areas.*

In 1973 Lake Levels were at record maximums, and as a result of pressure from suffering interests, the IJC urged the Levels Board to complete the study. At this time (January 30, 1973), the IJC responded to a United States Emergency Application by reducing the outflows from Lake Superior by 25% in order to alleviate high water conditions on the lower lakes. At present the IJC is still exercising this "emergency authority." The Levels Board published its report on December 7, 1973 (main report and seven appendices including: Hydrology and Hydraulics; Lake Regulation; Shore Property; Fish, Wildlife and Recreation; Commercial Navigation; Power; and Regulatory Works).

In its attempt to develop a plan which minimizes variation of levels, maximizes benefits to the Great Lakes as a whole and at the same time causes less than $200,000 average annual loss to any major economic interest on any lake, the Levels Board developed a series of regulation plans. The Board found that plans which maintained the lakes at the same position relative to their mean levels best fulfilled these objectives. The Levels Board reached five major conclusions as a result of its study:

- Small net benefits to the Great Lakes system would be achieved with a new regulation plan for Lake Superior which takes into consideration the levels of both Lake Superior and Lakes Michigan-Huron. Until January 1973 Lake Superior outflows were determined on the basis of Lake Superior levels only.

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* Of all the agencies which participated in the study, the U.S. Army Corps of Engineers is by far the best represented. Of the 144 participants in the study effort, 57 were from the Corps. The Canadian Department of Environment is second with only 20 representatives.

- Regulation of Lakes Michigan-Huron by the construction of works in the St. Clair and Detroit rivers does not warrant any further consideration

- Further study is needed of the alternatives for regulating Lake Erie and improving regulation of Lake Ontario, taking into account the full range of supplies received to date

- The hydrologic monitoring network of the Great Lakes basin should be progressively improved

- Appropriate authorities should act to institute land use zoning and structural setback requirements to reduce shoreline damage (IGLLB 1973, Main Report, pp. 251-252).

The Levels Board recommended that two regulation plans be considered for implementation: Plan SO-901 and Plan SEO-42P (now revised as Plan SEO-17P). Plan SO-901 calls for no new major construction beyond the existing regulatory works at the outlets of Lake Superior and Lake Ontario. However, this plan changes the rule for determining the Lake Superior outflow by taking into account the levels of Lakes Michigan-Huron (Lake Michigan and Lake Huron have the same water level). Plans SEO-42P and SEO-17P are the same as Plan SO-901 with the addition of a diversion canal at the outlet of Lake Erie.

The Levels Board generally did not include representatives of the Great Lakes states in the process of selecting regulation plans. When the IJC held a series of hearings on the Levels Board report in November 1974, the states were not fully aware of the methods and assumptions used by the Levels Board or of the impact of the various plans on state interests. For example, Wisconsin shore interests are located on both Lake Superior, which suffers a loss under Plan SO-901 and on Lake Michigan where benefits occur under the plan, but the relative losses and benefits to Wisconsin shore interests on these lakes were not known. Thus, in January 1975 an ad hoc state level committee was established to develop a state position on this issue. The committee consisted of members of state agencies, the University and the three coastal regional planning commissions. At this time the Lake Superior Project and one of the Water Resources Management Workshop groups began preparing, for the state of Wisconsin, five working papers which analyze the methods used by the Levels Board and the impacts of Plan SO-901, Plan SO-901 Mod 7, Plan SO-901 Mod 8 and Plan SEO-17P on Wisconsin.

## Format and Structure of this Report

This report is arranged as five working papers: I. Hydrology; II. Navigation; III. Shore Property and Recreation; IV. Wetlands, Fisheries and Water Quality; and V. Institutions. The University team performed the research for these working papers as a part of an eight week seminar during the summer of 1975. The University analysis relies largely on information supplied in the Levels Board report and on other basic data and computer programs provided by the U.S. Army Corps of Engineers. The working papers describe the Levels Board's methodology, suggest alternative methods for evaluating regulation plans and discuss the impacts of certain plans on Wisconsin. Because of the short period of time available to assess the Levels Board report, analyses which require substantial manipulation of data, such as studying how diversions and lake levels could be regulated together, were not performed.

# II. SUMMARIES OF THE UNIVERSITY STUDY GROUP REPORTS

## A. Hydrology

### INTRODUCTION

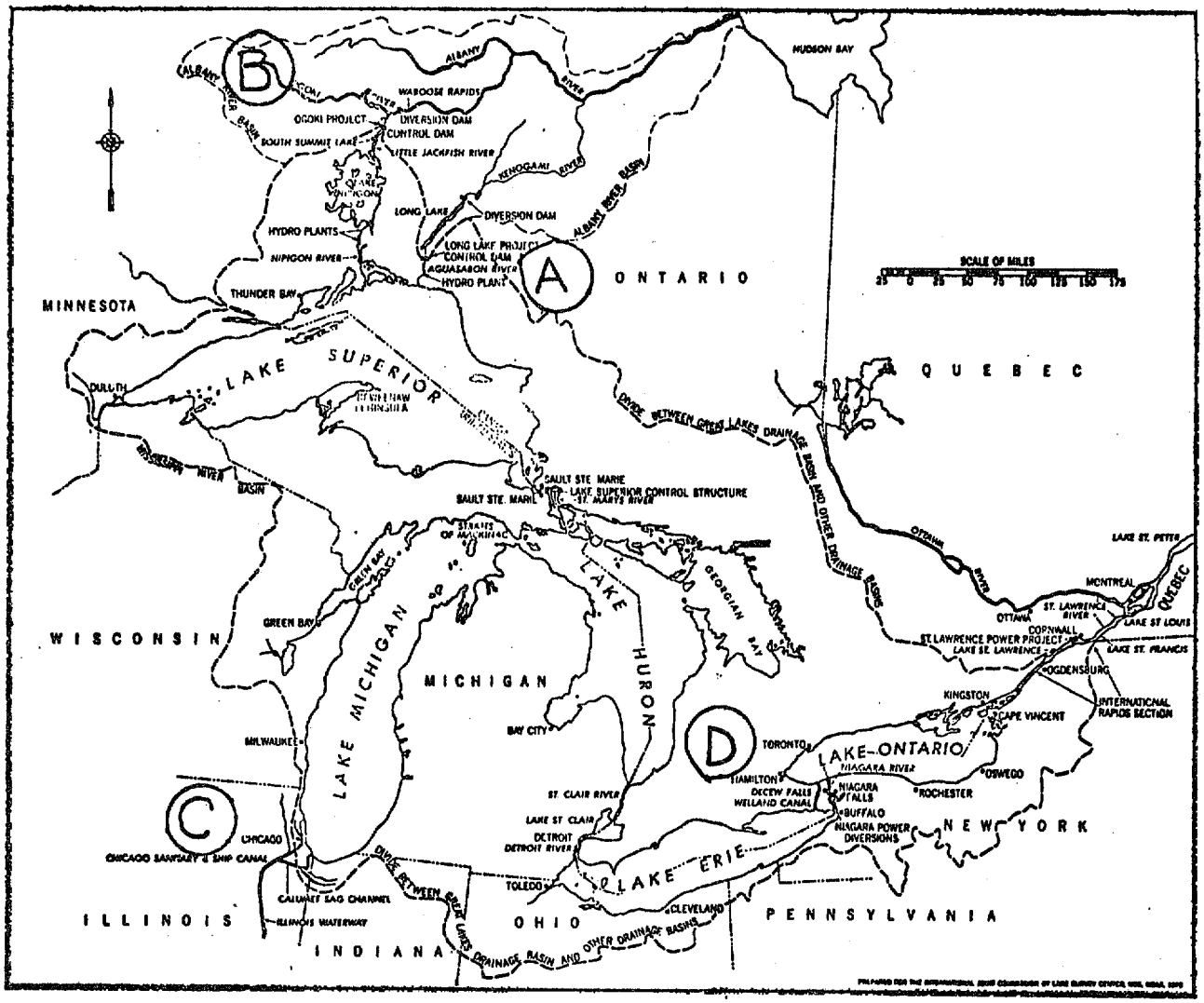
The fluctuations of water levels on the Great Lakes are influenced by natural and man-induced causes. Major natural agents include precipitation, runoff, evaporation, and the discharge capacity of connecting rivers. To a much lesser degree man modifies the levels with dams, locks, and diversions(see Figure). Man regulates the flows through the basin at only two places—in the St. Marys River, which connects Lakes Superior and Huron, and the outlet of Lake Ontario in the St. Lawrence River. The Long Lake and Ogoki diversions (A, B) and the diversions at Chicago (C) and the Welland Canal (D) are not operated according to levels on any of the Great Lakes. Under the 1964 Reference to the IJC the Levels Board examined alternative methods only within the basin of reducing the range of lake level stages. The hydrology section of the University report analyzes the Levels Board's hydrologic studies and the hydrologic aspects of the proposed plans.

### THE DATA BASE USED BY THE IGLLB

To evaluate the effects of alternative regulation plans the Levels Board needed to compare the levels produced by a plan with those yielded by existing operating rules. The historical record of lake levels is unsuitable as a data base for assessing the impact of proposed lake level management schemes because recorded levels reflect different effects of earlier regulation plans. Thus, the Levels Board developed a data base to serve as a "Basis-of-Comparison" for evaluating the effects of proposed management schemes. The Basis-of-Comparison (BOC) data set was simulated, by routing through the system, net basin supplies estimated from available data on lake levels, diversions and outflow measurements as recorded for the period 1900-1967. In the view of the Levels Board the 1900-1967 period represented the longest interval of reliable net basin supply data and incorporated considerable extremes of supplies. Using the operating rules, diversions, and channel configurations in effect in 1964 as constraints on the levels simulation procedure, the Levels Board hindcasted what the 1900-1967 levels would have been under these 1964 conditions. The names of the operating rules used in the BOC are the "September 1955 Modified Rule of 1949" for Lake Superior outflows and the "1958-D Rule" for Lake Onatrio outflows. One must appreciate that the BOC data base represents an artificially regulated lake system and therefore is not a reconstruction of lake levels free of man's influence. The BOC data serves as a benchmark series of levels to which the results of various regulation plans can be compared (RF Monograph 76-01-Hydrology, section II).

A serious criticism of this data base concerns the background climatic characteristics of the years represented in the sample interval 1900-1967. Over 30 years represented in the BOC data base (approximately 1930-1960) were characterized by relatively warm, dry climatic conditions which may occur less frequently in the next few decades. Studies of the historical record of climate in the Great Lakes region indicate that return frequencies of many characteristics of climate which dominated the first half of the twentieth century are not representative of climate recurrence frequencies determined from longer records. The relatively warm episode of the

# GREAT LAKES—ST. LAWRENCE RIVER DRAINAGE SYSTEM




Source: IGLLB 1973, Appendix B, p. B-2.

early to middle twentieth century may represent only a brief fluctuation from somewhat cooler climatic conditions which have characterized the last three to four centuries. Indeed, Bryson (1974) has noted the unusual character of the climate of the 1931-1969 base period and reported that "there appears to be nothing like it in the past 1,000 years." Cooler and wetter climatic conditions will result in net basin supplies which are larger than those represented in the BOC data base. Regulation plans such as SO-901, which tend to raise Lake Superior levels, will cause more shore damage on that lake than the Levels Board indicates.

forecasting technology, it is impossible to accurately predict how long the present period of high supplies might last, but the present trend toward cooler and wetter conditions, which has occurred since approximately 1950, is likely to continue during the next few decades. Thus, while long-term fluctuations do not occur in regular cycles, there are periods when high or low lake levels persist (RF Monograph 76-01-Hydrology, section III).

## REGULATION PLANS

Each of the alternatives to the BOC conditions studied by the Levels Board modifies existing regulation plans or structural works in the channels. The Levels Board reported favorable results for two types of operating rules. First, the SO plans, such as SO-901 and SO-901 Mod 7 and Mod 8, regulate Lakes Superior and Ontario together by retaining the existing operating rule for Lake Ontario (1958-D) and altering the Lake Superior operating principle. Instead of regulating the outflows from Lake Superior according to shore property, power, and navigation interests on Lake Superior or the St. Marys River, the SO plans attempt to balance the levels of Lake Superior with levels on Lakes Michigan-Huron. Secondly, regulation plans such as SEO-42P and SEO-17P incorporate the balancing concept for regulating Lake Superior in addition to structural changes in the Niagara River outlet from Lake Erie.

*Plan SO-901.* The balancing concept in Plan SO-901 is to maintain the levels of Lakes Superior, Michigan, and Huron as close as possible to their respective long-term mean levels. Under the rules of the plan, the standard deviations of the beginning-of-the-month levels for both Lake Superior and Lakes Michigan-Huron are compared to determine which of the two lake systems represents the larger deviation from its long-term mean lake level. Lake Superior outflow is then regulated in favor of returning the lake having the greater deviation closer to its long-term mean level. Plan SO-901 is relatively similar to the September 1955 Modified Rule of 1949 which guided the regulation of Lake Superior outflow until February 1973. The principal difference between the 1955 Modified Rule and Plan SO-901 is the incorporation of Lakes Michigan and Huron levels into the determination of the Lake Superior discharge. This balancing principle has been in effect since January 30, 1973. Relative to the BOC conditions, Plan SO-901 tends to raise Lake Superior levels in high net basin supply periods, such as 1972-1974, and lower the levels during years when the levels are already low, such as the 1930s. Plan SO-901, however, does raise the minimum levels experienced. On Lakes Michigan-Huron Plan SO-901 reduces the chances of having extremely high or low levels (RF Monograph 76-01-Hydrology, section IV).

*Mods 7 and 8 of Plan SO-901.* The Levels Board examined modifications of Plan SO-901 to determine if additional benefits could be obtained under the general rules of regulation set by Plan SO-901. Plans SO-901 Mod 7 and Mod 8 increase the range of permissible levels on Lake Superior to benefit the other lakes (Table 1). Relative to BOC, Mod 7 and Mod 8 lower the mean level of Lake Superior by 0.4 feet and 0.7 feet, respectively. Although the Mod plans would use the same control works as Plan SO-901, all harbors and channels would require dredging because of the lower levels.

*Plans SEO-42P and SEO-17P.* The SEO plans involve the coordinated regulation of Lakes Superior, Erie and Ontario. To increase the discharge capacity from Lake Erie, the SEO plans include a diversion channel across Squaw Island thereby providing an additional link between the Black Rock Canal and the Upper Niagara River. Plan SEO-42P, a preliminary plan developed by the Levels Board, calls for an additional outflow during high water level periods of 8,000 cubic feet per second (cfs) from Lake Erie. Plan SEO-17P, which is a refinement of SEO-42P developed by the North Central Division of the U.S. Army Corps of Engineers, specifies a maximum diversion of 17,500 cfs in January-April and 10,000 cfs in May-December (U.S. Army Corps of Engineers 1974). Under the SEO plans Lake Superior would be regulated according to Plan SO-901, and Lake Ontario in accordance with the 1958-D criteria (subject to some modifications). Because of data limitations the University group could not directly analyze the levels generated by Plan SEO-17P. Inspection of the report prepared by the North Central Division indicates that these plans have nearly identical impacts upon Lakes Superior and Michigan-Huron (Table 1). A more detailed discussion of how these regulation plans affect Lakes Superior and Michigan-Huron follows in section III.

## PLAN EVALUATION

To evaluate these regulation plans the University work group examined the hydrologic impacts of the plans from several different perspectives. Although the Levels Board made an admirable effort to estimate the impact of the regulation plans, the University study group concluded that the following questions needed evaluation:

- How often do the plans actually work to balance the lakes, and how often is their use constrained by outflow limitations in the St. Marys River?
- How do the plans affect the incidence of extreme lake levels?
- How would the plans affect lake level fluctuations during periods of extreme net basin supplies?

# TABLE 1 SUMMARY RANGES OF LAKE LEVEL STAGES AND PROJECTED ECONOMIC IMPACTS OF REGULATION PLANS

MEAN MONTHLY LAKE LEVELS (FEET ABOVE SEA LEVEL—IGLD) 1900-1973

| | Basis-of-Comparison | SO-901 | SO-901 Mod 7 | SO-901 Mod 8 | SEO-42P | SEO-17P |
|---|---|---|---|---|---|---|
| LAKE SUPERIOR | | | | | | |
| Mean | 600.41 | 600.46 | 599.99 | 599.76 | 600.41 | 600.38 |
| Max | 601.91 | 602.00 | 602.08 | 601.93 | 601.95 | 601.92 |
| Min | 598.36 | 598.80 | 597.89 | 597.59 | 598.76 | 598.73 |
| Range | 3.55 | 3.20 | 4.19 | 4.34 | 3.19 | 3.19 |
| Standard Deviation | 0.65 | 0.67 | 0.86 | 0.89 | 0.67 | ------ |
| LAKES MICHIGAN-HURON* | | | | | | |
| Mean | 578.04 | 578.04 | 578.05 | 578.05 | 577.94 | 577.87 |
| Max | 581.23 | 580.80 | 580.51 | 580.47 | 580.67 | 580.52 |
| Min | 575.12 | 575.48 | 575.67 | 575.67 | 575.39 | 575.35 |
| Range | 6.11 | 5.32 | 4.84 | 4.80 | 5.28 | 5.17 |
| Standard Deviation | 1.19 | 1.07 | 0.99 | 0.98 | 1.06 | ------ |
| LAKE ERIE | | | | | | |
| Mean | 570.69 | 570.69 | 570.62 | 570.63 | 570.43 | 570.30 |
| Max | 573.75 | 573.53 | 572.90 | 572.82 | 573.19 | 572.97 |
| Min | 567.97 | 568.13 | 568.21 | 568.25 | 567.97 | 567.91 |
| Range | 5.78 | 5.40 | 4.69 | 4.57 | 5.22 | 5.06 |
| Standard Deviation | 1.03 | 0.97 | ------ | ------ | 0.93 | ------ |
| LAKE ONTARIO | | | | | | |
| Mean | 244.57 | 244.54 | 244.56 | 244.56 | 244.51 | 244.40 |
| Max | 249.27 | 247.90 | 246.89 | 246.89 | 247.92 | 247.48 |
| Min | 240.82 | 241.48 | 241.92 | 242.13 | 241.13 | 241.41 |
| Range | 8.45 | 6.42 | 4.97 | 4.76 | 6.79 | 6.07 |
| Standard Deviation | 1.05 | 0.92 | ------ | ------ | 0.96 | ------ |
| APPROXIMATE ANNUAL BENEFITS ($ MILLIONS)** | | | | | | |
| Power | 0.0 | + 0.64 | + 0.6 | + 0.9 | + 0.00 | - 0.52 |
| Navigation*** | 0.0 | + 0.93 | + 2.9 | + 2.0 | + 0.63 | + 0.29 |
| Shore Property | 0.0 | + 0.73 | + 2.7 | + 3.1 | + 7.74 | + 9.77 |
| TOTAL | 0.0 | + 2.30 | + 6.2 | + 6.0 | + 8.37 | + 9.54 |
| GEOGRAPHICAL BREAKDOWN OF SHORE PROPERTY BENEFITS ($ MILLIONS) | | | | | | |
| Superior | 0.0 | - 0.12 | + 1.2 | + 1.5 | + 0.15 | + 0.30 |
| Michigan-Huron | 0.0 | + 0.42 | + 1.2 | + 1.3 | + 2.39 | + 3.13 |
| Erie | 0.0 | + 0.46 | + 0.2 | + 0.2 | + 4.00 | + 4.80 |
| Ontario | 0.0 | - 0.03 | + 0.1 | + 0.1 | + 1.20 | + 1.54 |
| TOTAL | 0.0 | + 0.73 | + 2.7 | + 3.1 | + 7.74 | + 9.77 |

Sources: U.S. Army Corps of Engineers 1974.
University of Wisconsin-Madison 1975.
IGLLB 1973, Main Report.

Notes: * 1962 outlet conditions.
** Average annual benefits for the BOC and all plans except SEO-17P were calculated by the Levels Board for 1900-1967 levels. Benefits from Plans SO-901 and SEO-42P and shore benefits from SEO-17P calculated with detailed analysis. Other economic effects calculated with generalized loss curves. Shore property benefits from SEO-17P are to U.S. shores only.
*** Navigation benefits are computed for traffic routes, not for individual lakes.

The University analyses of these pertinent questions are briefly summarized below.

The proposed lake level management plans have modest effects on the long-term mean levels of the Great Lakes. All five of the proposed lake level regulation plans have the potential to exert great impacts on lake levels, but this potential is never achieved because full-scale implementation of the plans would result in major negative impacts to certain interest groups, e.g., shore property, navigation, and power. University analyses of 1900-1973 net basin supplies revealed that Plan SO-901 would have been constrained by rule limitations affecting maximum or minimum outflow capacities about 59% of the time. Mods 7 and 8 of Plan SO-901 are constrained 57% and 54% of the time. Although no comparable analyses were conducted for the SEO plans, the rule constraints would affect them in a similar way because the SEO plans incorporate the same Lake Superior discharge rule as that of Plan SO-901 (RF Monograph 76-01-Hydrology, section IV).

The impact of these five regulation plans on the number of occurrences of extremely high and extremely low water levels is also modest, but the effect is significant because large damages are frequently associated with such levels. Plans SO-901 and SEO-42P increase the frequency of levels above 601.4 feet on Lake Superior and reduce the extreme high levels for Lakes Michigan and Huron (Table 2). Mods 7 and 8 of Plan SO-901 reduce the number of extremely high levels on both Lakes Superior and Michigan-Huron, but the benefits from these changes are partly offset by an associated major increase in the frequency of extreme low levels on Lake Superior (Table 2).

The effectiveness of the SO regulation principle to reduce extreme levels on both Lake Superior and Lakes Michigan-Huron depends in part on the pattern of occurrence of net basin supplies. Analyses suggest that SO regulation is most effective if high or low net basin supplies do not occur in clustered sequences, but climate studies indicate that clustering or grouping of supply sequences is common. The effect of SO regulation further lowers the levels of Lake Superior during "dry" periods such as the 1930s or mid-1960s, while raising the levels of Lake Superior during periods of high net basin supplies such as 1972-1974 by as much as 0.9 feet (RF Monograph 76-01-Hydrology, section IV).

## DIVERSIONS

Controlling the diversions at Chicago and into Lake Superior is not within the IJC's jurisdiction, and the IJC did not authorize the Levels Board to study the feasibility of incorporating the diversions into the proposed regulation plans. The Long Lake and Ogoki River diversions into Lake Superior are operated by the Hydro Electric Power Commission of Ontario. Since 1943 the total flow from these diversions has averaged 5,450 cfs. These diversions have not raised the levels of Lake Superior because the additional flows have been incorporated into operating rules for that lake.

## TABLE 2 COMPARISON OF EFFECTS OF MANAGEMENT PLANS

EFFECTS OF REGULATION PLANS ON LAKE SUPERIOR (IN FEET)

| Plan | Mean | Standard Deviation | Number of Monthly Means: <600.00 | >601.40 | >601.60 | Total Range |
|---|---|---|---|---|---|---|
| BOC | 600.41 | .65 | 214 | 27 | 16 | 3.55 |
| SO-901 | 600.46 | .67 | 208 | 46 | 17 | 3.20 |
| SEO-42P | 600.41 | .67 | 223 | 37 | 16 | 3.19 |
| Mod 7 | 599.99 | .86 | 445 | 18 | 11 | 4.19 |
| Mod 8 | 599.76 | .89 | 516 | 12 | 9 | 4.34 |

EFFECTS OF REGULATION PLANS ON LAKES MICHIGAN-HURON (IN FEET)

| Plan | Mean | Standard Deviation | Number of Monthly Means; <576.80 | >579.60 | >580.00 | Total Range |
|---|---|---|---|---|---|---|
| BOC | 578.04 | 1.19 | 131 | 68 | 28 | 6.11 |
| SO-901 | 578.04 | 1.07 | 109 | 44 | 17 | 5.32 |
| SEO-42P | 577.94 | 1.06 | 129 | 30 | 14 | 5.28 |
| Mod 7 | 578.05 | .99 | 87 | 29 | 12 | 4.84 |
| Mod 8 | 578.05 | .98 | 82 | 29 | 10 | 4.80 |

Source: University of Wisconsin-Madison 1975.

The magnitude of the diversion from Lake Michigan through the Chicago Sanitary and Ship Canal is limited by a 1967 Supreme Court decree to a five-year average annual rate of 3,200 cfs, with an average for any one year not to exceed 3,520 cfs. This diversion has served four main purposes:

- To dilute the effluent of the Chicago sanitary district
- To allow for navigation in canals around Chicago
- To provide for public water supply
- To increase power generation at Lockport and Marseilles, Illinois.

Approximately 2,200 cfs of the total diversion represents water pumped for public use or surface runoff and groundwater that would have flowed into Lake Michigan. The diversion of approximately 3,200 cfs from Lake Michigan lowers the levels of that lake by 0.23 feet, while a diversion of 10,000 cfs would lower Lake Michigan levels by 0.75 feet after fifteen years. The Chicago and Long Lake-Ogoki diversions could be increased or decreased according to the lake levels, but political and economic considerations are the main obstacles to a variable diversion scheme (RF Monograph 76-01-Hydrology, and RF Monograph 76-05-Institutions).

## B. Navigation

Navigation on the Great Lakes is an important economic interest of Wisconsin and therefore is an integral consideration in development of state policy on lake level regulation. Over $500 million in iron ore and grain alone were shipped from Duluth-Superior harbor in 1970. The University analysis of Appendix E, Commercial Navigation, (IGLLB 1973) of the Levels Board report concentrated upon how the regulation plans affect the economics of Great Lakes shipping. Of particular importance are the data base, methodology and assumptions used by the Levels Board. In general, the Levels Board methodology is sound, but the assumptions and the data base used are sufficiently questionable that the numerical estimates of benefits are overstated. The navigation benefits from Plan SO-901 may be only one-third to two-thirds of the value estimated by the Levels Board.

The Levels Board based its calculation of navigation benefits and losses on projections of growth in shipment of four commodities: iron ore, grain, coal and limestone. Low, medium and high growth projections were made for 1970, 1995 and 2020. The Levels Board used the medium growth projection to calculate navigation benefits. The University analysis, however, indicates that the low projection conforms more closely to longer-term trends in commodity growth than the medium growth projection. The University used a 1920 to 1970 trend and compared it with the 1940 to 1970 trend used by the Levels Board. Especially high were the Levels Board's estimates of growth in shipment of iron ore (five times the long-term growth rate). Use of the low growth projection rather than the medium growth projection results in a 29% reduction in navigation benefits.

The assumptions about vessel size and capacity are another important part of calculating navigation benefits and losses because larger ships cause much more dramatic changes in benefits or losses relative to lake level than do small ships. The Levels Board classified ships in ten categories according to size and then projected the future distribution of the United States and Canadian fleets among these categories. Whereas the Levels Board projected rapid expansion in the larger sizes (731-foot to 1,000-foot lengths) and decrease in the smaller sizes (less than 649-foot lengths), the University study shows that the historical pattern of growth suggests that increasing numbers of ships of all size classes will be built.

The most important factors in determining vessel size and capacity are lock size, dock capacity, and dock location. In this regard the St. Lawrence Seaway and the St. Marys River are major constraints on vessel size with locks limited at 730 feet by 75 feet and 1,000 feet by 105 feet, respectively. The University team questions the Levels Board assumption that the Welland Canal will be expanded to accommodate 1,000-foot long ships within 20 years. Considering the long lead times required to plan such a change and prepare required information such as Environmental Impact Statements, 20 years is probably too short a period.

The Levels Board method for calculating navigation benefits shows that navigation costs are sensitive to slight changes in lake levels, such as that caused by the recommended regulation plans, and thus, it is important to understand the accuracy of the method. A major error in the Levels Board analysis is the inclusion of fixed costs in calculating navigation benefits and losses. Fixed costs, which include vessel amortization, interest and overhead and account for 40% of the operating costs, should not be included in calculating benefits unless fewer ships are needed. The Levels Board, however, uses the same number of ships in the fleet for all of the regulation plans considered. Another important consideration is that navigation benefits from Plan SO-901 occur least during periods of high water levels. Since net basin supplies to the Great Lakes will likely be higher during the next few decades than they were for much of the 1900-1967 period used by the Levels Board as a Basis-of-Comparison, navigation benefits will be less than the Levels Board report indicates (RF Monograph 76-02-Navigation).

## C. Shore Property and Recreation

Because Wisconsin borders both Lake Michigan and Lake Superior, the distribution of economic effects of the proposed regulation plans among the shore interests on each lake is a major state concern. Shore property is an important component of the estimated benefits of these plans. Erosion and inundation, for example, account for 24% of the total estimated benefits of Plan SO-901 and 82% of the benefits of Plan SEO-17P. Recreational beaches, which account for 9.6% of the benefits of Plan SO-901 and 21% of the Plan SEO-17P benefits,* is also an important part of shore considerations. While the IGLLB's conclusion that

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* Because there are losses to power interests under Plan SEO-17P, erosion and inundation benefits and recreation benefits total more than 100% of the overall benefits of the plan.

either of these plans will produce net benefits to Great Lakes shore interests appears to be valid, substantial uncertainty is associated with the IGLLB estimates. The IGLLB analysis of the impact of Plan SO-901 on shore property also indicates that losses on Lake Superior may exceed estimated benefits on Lake Michigan.

Study of the effect of Great Lakes level fluctuation on shore property has not occurred until relatively recently because not until after the Second World War had shoreline development proceeded to such an extent that shore damage was considered a national problem. In 1951-52 when Great Lakes levels were at a peak, an estimated $61 million damage occurred to shore property in the United States (U.S. Army Corps of Engineers 1971), and since then development has been even more rapid. Many property owners failed to recognize that shorelands recede naturally because the Great Lakes are geologically young and have not reached a stable condition. As lake levels reached record highs in the early 1970s, urban areas suffered severe damage.

Appendices C, Shore Property, and D, Fish, Wildlife and Recreation, present the findings of the IGLLB Shore Property Subcommittee. These reports, which discuss the impact of regulation on erosion and inundation, recreation, marine structures, sewer outfalls and water intakes, are the first attempts to project Great Lakes shore damage on a basin-wide basis. Because such projection is so new, necessary information about shore damage and shore erosion processes is incomplete, and methods are still rather crude. The University study focuses on the two most economically significant aspects of the IGLLB shore property analysis, erosion and inundation, and recreation. The Shore Property and Recreation Working Paper attempts (1) to clarify the IGLLB's procedure, (2) to point out questionable aspects of the study, and (3) to suggest alternative approaches where appropriate.

The IGLLB analysis of the impact of various regulation plans on United States erosion and flood damage is based on a 1952 damage survey, a 1965 Lake Erie study, and a 1966 survey and projection of land use, property value and shore protection. All three studies were performed by the U.S. Army Corps of Engineers. The only comprehensive survey of Great Lakes shore damage from high lake levels was conducted during the spring of 1952. It consists of damage data submitted voluntarily by United States shore property owners and lists estimated losses from May 1951 through April 1952. Losses include damages to structures other than protective structures, value of land lost to erosion, and flooding damage to crops or improvements.

The IGLLB method for determining shore erosion and flood damage is based on a 1965 Lake Erie study. The study, which is only a crude analysis of shore damage from wave attack, assumes that shore damage is curvilinearily related to ultimate water level; so for each increment of increase in ultimate water level, damages increase exponentially. The monthly ultimate water level, calculated by using representative shore profiles and wind data, represents the highest point on the shore which a wave reaches in a particular month. By assuming a $0 damage ultimate water level and a curvilinear stage (water level)-damage curve, the IGLLB established state-damage curves for each of 36 United States reaches by approximating the total estimated damage to each reach for the May 1951-April 1952 period. A curve was considered adequate if the sum of the damages indicated by each of the twelve monthly ultimate water levels for that period approximately equaled the total estimated damage to a reach as indicated by the 1952 survey. Before the stage-damage curves were developed, the IGLLB updated the 1952 damage data to 1966 prices and shore conditions (protection and land use).

In 1966 Great Lakes district offices of the U.S. Army Corps of Engineers surveyed for the IGLLB current shore protection (natural and man-made) and land use. They also projected shore protection, land use and property values for 1980, 2000, and 2020 based primarily on available projections of population, growth, and income. Critical assumptions in the Levels Board's analysis are (1) that protected property will suffer negligible damage, and (2) that a parcel of property will be protected as soon as the expected damages exceed the cost of protection. The IGLLB incorporated these assumptions with the projections to calculate indices of change in shore damage (percent of change in the 1952 damages updated to 1966 conditions) for each reach. Observations of shore property damage in recent years suggests that these assumptions are too broad. Currently protected property may be significantly damaged depending on the type of shore protection and on neighboring protection. Property owners may also suffer severe property damage before deciding to install protective measures rather than protect their property before damage occurs.

The IGLLB used the following procedure to determine average annual damage for each United States reach. First, climatic information for as much of the 1900-1967 base period as possible was used to determine monthly ultimate water levels. Secondly, average damage per month per mile was determined from the stage-damage curve and then multiplied by the number of unprotected miles of shore in 1966. Thirdly, this number was multiplied by the indices of change in shore damage for 1980, 2000, and 2020. Finally, using a 7% interest rate the values of damages were discounted to obtain average annual damage for each reach.

The method described above provides at best a very general indication of possible losses and not an accurate quantitative analysis. The Levels Board recognized that, while their method is imprecise, it does provide a uniform basis for comparing regulation plans. However, the range of possible benefits under various regulation plans is also an important consideration. Two major areas of uncertainty in the shore property analysis are (1) future net basin supplies to the Great Lakes, and (2) population and income projections used to estimate property value, land use and shore protection. These two aspects largely determine the possible range of benefits and losses under the plans, and the merit of one plan relative to another varies according to changes in net basin supplies and in projections of population and income. The Levels Board evaluated Plan SO-901 under ten simulated supply sequences, but it did not evaluate any other plans in the same manner. The simulations for Plan SO-901, for example, show that losses to Lake Superior shore interests range from $100,000 to $2,300,000 while gains to Lakes Michigan and Huron shore interests range from $300,000 to $1,000,000. In four of the ten cases, shore losses on Lake Superior equal or exceed the shore benefits of Plan SO-901 to Lakes Michigan-Huron.

In addition to uncertainty, bias in the IGLLB method for determining wave breaking depth affects the calculation of shore benefits. The method is biased in favor of plans which lower Lake Michigan levels. The IGLLB method overstates breaking depths when regulation raises water levels and understates breaking depths when levels are lowered. The bias occurs because the absolute amount of damage on Lake Michigan is greater than that on Lake Superior.

In determining the economic effects of lake level regulation on recreation, the IGLLB considered recreational beaches and recreational boating. Because the proposed regulation plans alter mean monthly lake levels relatively little, the IGLLB decided that the plans would not have a measurable economic impact on boating. Thus, the IGLLB calculations of recreational benefits are based solely on the effect of regulation on beaches. These beach benefits are determined on the basis of changes in available beach area under various regulation plans. The Levels Board's use of beach area to compute benefits, however, involves two important questionable assumptions which subject the Levels Board's numerical estimates to considerable uncertainty. First, the IGLLB assumed that any increase in beach acreage will yield a benefit because demand for beach recreation exceeds the supply of beaches. Recent studies, however, indicate that the popularity of swimming may be leveling off or declining. Secondly, numerous authors have found that projecting recreation demand requires consideration of many variables besides beach acreage (RF Monograph 76-03-Shore Property and Recreation).

This uncertainty in the calculation of recreation benefits is important because these benefits account for a significant portion of the total benefits of the plans which the IGLLB recommended for consideration. For example, the IGLLB estimates that Plan SO-901 generates $228,000 average annual benefits for beaches (9.6% of the estimated total benefits). Estimated recreational benefits under Plan SEO-17P are even more substantial at $2,076,000 (21% of the total). Furthermore, the IGLLB calculation of recreation benefits is very sensitive to very slight changes in lake levels. The maximum differences in Lakes Michigan-Huron levels between Plan SO-901 and Plan SEO-42P is 0.13 feet using the 1900-1973 period, but recreation benefits on these lakes are $850,000 under Plan SEO-42P and $82,000 under Plan SO-901. Doubt concerning the accuracy of the IGLLB projections does not appreciably diminish the relevance of using these figures to compare regulation plans, but the above considerations indicate that the recreation benefits may be overstated.

## D. Wetlands, Fisheries, and Water Quality

Determining the impacts of various lake level regulation plans proposed by the IGLLB on wetlands, fisheries, wildlife, and water quality of the Great Lakes is a difficult task. Accurate prediction of impacts is hampered by the lack of data and incomplete understanding of the role lake level fluctuations play on plant succession, nutrient exchange, shoreline erosion, and the life cycles of plants and animals. Some water level fluctuations are not only natural and beneficial to coastal wetland ecosystems, but are in fact necessary for their maintenance as 'pulse-stable' communities. Furthermore, shoreline erosion and near-shore turbidity are natural phenomena to which the wetlands and wildlife have adapted.

## WETLANDS

After field investigations of Wisconsin's Great Lakes wetlands, discussions with knowledgeable resource personnel, and a review of relevant literature, the University study group developed lake levels related criteria for the maintenance of wetlands and wildlife (RF Monograph 76-04--Wetlands, Fisheries, and Water Quality). For Lake Superior the criteria are:

- Low frequency of extreme high levels
- Maintenance of the mean elevation of the historical record
- Maintenance of a range of fluctuation consistent with the historical record
- Duration of extreme levels similar to that of the historical record
- Maintenance of a pattern of annual fluctuation consistent with the historical record.

Of the five Great Lakes the mean monthly levels of Lake Superior have varied the least--only 3.6 feet from 1900-1973. Therefore, the gradient between plant communities in relatively dry soils ('mesic') and wetter soils ('hydric') is compressed within a relatively small range of water levels. Lower mean levels or greater frequency of low levels will permit more upland species to colonize the wetland while reducing the suitability of the wetland for 'hydric' species. Conversely, higher mean levels or increasing numbers of high levels will encourage the succession of 'hydric' species. Extreme high levels in conjunction with storms or seiches can endanger sand spits, bars, and barrier beaches which protect most of the wetlands along Lake Superior, such as Allouez Bay, Raspberry Bay, and the Kakagon Sloughs.

Long-term oscillations in mean water levels affect not only the wetlands but also the furbearers and water fowl dependent upon them as habitat. Plan SEO-17P and Plan SO-901 neither appreciably alter the long-term mean level of Lake Superior nor disrupt the annual fluctuations. Although these plans reduce the range of stage on Lake Superior, they do not eliminate the natural long-term oscillations which maintain the wetlands. Plan SO-901, however, increases the frequency of Lake Superior levels above 601.4 feet, which could affect the protective sand bars.

For Lake Michigan wetlands the University group recommends:

- Slightly reduce the range of lake levels
- Maintain the mean elevation of the historical record
- Maintain a pattern of annual fluctuation consistent with the historical record.

The extreme range of lake levels from 1964-1975 (approximately 6 feet) has dramatically affected wetlands of Wisconsin's Lake Michigan shoreline. In July 1975 the flooding of wetlands in Green Bay was eliminating large tracts of emergent aquatic plants and killing trees at the upland edge of the wetland. At the same time the higher levels maintain the plant communities in swales by flooding out the shrubs that invade during dry years. Although the recent extremely high levels on Lake Michigan benefit some plant species, the University study group concludes that a small reduction in the range of water levels could decrease the extent of tree deaths and ice damage without damaging the wetlands' pulse-stability. Plans SEO-42P, SEO-17P, SO-901, and SO-901 Mod 7 and Mod 8 all reduce the range of Lake Michigan levels. Because these regulation plans will not change the mean elevation of Lake Michigan by more than 0.10 feet, the wetlands will remain within their exisiting zones along the shoreline.

## FISHERIES

The effects of the proposed regulation plans on the fishery resources of Lakes Superior and Michigan are important to Wisconsin, because the state has viable commercial and recreational fishing industries. Since past actions of man, such as over-exploitation, introduction of exogenous species, and pollution have dramatically affected the fisheries' species composition, it is wise to investigate the implications for fishing of further modifying Great Lakes water levels.

To evaluate the impacts of the proposed regulation plans on fish, the University study group examined potential changes in fish habitat due to lake levels. Of primary importance are the near-shore areas, which are the most biologically productive regions in the lakes and the places most affected by changing water levels. In addition to being spawning grounds, shallow water areas support aquatic plant communities which provide food, shade, and protection for fish.

As noted earlier, water level changes alter the aquatic plant community. In the short run, higher levels can provide more favorable spawning and/or nursery sites if the wetland gradient is slight. For example, return of yellow perch to lower Green Bay has been partly attributed to the flooding of the shrub-carr community which created ideal spawning sites, but any increase in the duration and/or frequency of high lake levels could allow undesirable species, such as carp, to alter the flooded habitat and displace more desirable species.

Increased turbidity and siltation resulting from erosion of red clay banks along Lake Superior could be detrimental to fish in that lake. State fishery specialists have expressed concern that greater turbidity could interfere with the northern pike's sight-feeding or discourage spawning runs of salmonid species. Greater siltation could also alter the gravelly substrate and impair spawning efforts of lake trout, lake herring, and the Menomonee whitefish. High water levels, particularly when temporarily increased by a seiche, may reduce or reverse the flow in some stream mouths. Such backwater effects lower dissolved oxygen concentrations and impair spawning runs for rainbow, brown and steelhead trout.

After considering these impacts of lake level changes on fish, the University study group proposes the following criteria for a regulation plan. As in the evaluation of wetlands, appreciation for the complexities of the Great Lakes fisheries recommends maintenance of levels similar to those of the historical record. For Lake Superior and Lake Michigan the following criteria are suggested:

1. *Frequency of Extreme Stages and Mean Levels Similar to that of the Historical Record*

Frequent low levels or a lower mean may disrupt spawning in shallow areas by exposing the bottom substrate to air or waves. Frequent high levels could be detrimental to fish by increasing turbidity, siltation, and backwater effects;

2. *Maintenance of a Range of Fluctuation Similar to the Historical Record*

The range of fluctuation should be maintained as occasional extreme levels are beneficial to fisheries. Extreme high levels result in increased productivity of warm water species, as the area of suitable habitat is greater. Low levels allow vegetation to grow in areas which are subsequently inundated, thus providing food, shelter, and habitat for warm water species. The range should not be significantly increased because this would increase the severity of the detrimental effects of extreme levels on fisheries:

3. *Duration of Extreme Levels Similar to the Historical Record*

A longer duration of extreme levels would exacerbate the problems that result from such levels (criterion #1). An additional concern is the longer periods of high levels may allow carp to alter the habitat in littoral and wetland areas and displace more desirable species;

4. *Maintenance of the Same Pattern of Annual Fluctuation*

The seasonal pattern of lake level fluctuation on Lake Superior has been quite constant throughout the historic record. Because the fish of the lake have adapted to this pattern, any alteration could be detrimental to the fisheries. However, none of the regulation plans will alter the seasonal pattern of fluctuation on Lakes Superior or Michigan.

Evaluation of how well the different regulation plans meet these criteria is integrated into the discussion of each plan.

## WATER QUALITY

Lake levels tangentially affect the following aspects of Great Lakes water quality: turbidity, effectiveness of water intakes and sewer outfalls, the amount of dredging required, the security of dredge disposal sites, and backwater effects in stream mouths. An important source of turbidity for the Great Lakes is shore erosion--particularly on the south shore of Lake Superior where highly erodible red clay banks comprise much of the shoreline. Although high lake levels accelerate erosion, other forces independent of lake levels, such as groundwater seepage, soil mechanics, and surface water runoff, contribute to the process. The fraction of overall turbidity attributable to lake level changes has not been estimated for the Great Lakes. Further research is required before one can reasonably estimate regulation's impact upon turbidity and subsequently its effects on fish and domestic water supplies.

Extreme water levels impair the operation of water intake and wastewater treatment facilities on the Great Lakes. An Environmental Protection Agency (EPA) survey of water intake and sewer outfall facilities on the lakes found that high water levels affected approximately 17 (5%) of the water intakes and 21 (10%) of the wastewater treatment plants, with some damage resulting from erosion and flooding. For example, in Ashland, Wisconsin, high water levels have accelerated erosion near the water and wastewater treatment facilities requiring expenditures for shore protection materials. Aside from the turbidity and erosion problems, the IGLLB concluded that higher water levels generally benefit water intake facilities by reducing their pumping costs.

The EPA survey for the IGLLB also found that during low water level periods "54(18%) of the water intake facilities surveyed reported that the quantity of water pumped was reduced, and 45 (15%) of the facilities reported the quality of water pumped was affected" (IGLLB 1973, Appendix C, p. C-167). In the low water level periods when dilution of the effluent from sewer outfalls is impaired the following water quality problems may become particularly apparent in connecting channels: high bacterial counts, increased chlorination and chemical treatment, and taste and odor problems.

Implementing a regulation plan such as SO-901 Mod 7 or Mod 8 which lowers the mean or increases the frequency of low levels on Lake Superior will require dredging of harbors and connecting channels. The principal problem of dredging is the disposal of polluted dredge spoils. Section 123 of the Rivers and Harbors Act of 1970 (PL 91-611) explicitly requires confinement of spoil classified as polluted. Dike disposal is required for such materials and is considerably more expensive than open lake disposal. Because wetlands are frequently used as disposal sites, use of the Mod plans could indirectly destroy wildlife habitat. Runoff and seepage from diked disposal sites or open lake dumping of dredge spoils also could impair water quality.

In addition to dredge spoil sites, ash pits, sanitary landfills, and other disposal areas are found adjacent to the lakes and may be flooded or damaged during periods of high levels. For example, the ashpit and coal storage areas of the Lake Superior District Power Company plant in Ashland, Wisconsin, have been flooded during the recent high levels. This could increase the turbidity and alter the pH of the nearby lake water.

The water quality of low-lying wetlands and estuaries could be harmed by backwater effects during periods of high water levels. Decreased flow through these areas may increase pollutant concentrations or lower the levels of dissolved oxygen below EPA minimum standards.

Further research is necessary before definitive statements can be made about the environmental impacts of new regulation plans. With respect to the criteria suggested above, the University study group concludes that Plans SO-901 and SEO-17P (SEO-42P) probably would not harm wetlands, fisheries, and water quality in Lakes Superior and Michigan. Although these plans meet most of the criteria suggested above, the impacts of SO-901 and SEO-17P on Lake Superior sand spits and bars should be monitored.

## E. INSTITUTIONS

The problems associated with fluctuating water levels are not new. Since 1909 when the United States and Canada signed the Boundary Waters Treaty and created the IJC, these countries have recognized a mutual concern for how their citizens use the Great Lakes. In 1914 the IJC issued Orders of Approval for two companies, one in Michigan and the other in Ontario, to build a dam on the St. Marys River and generate hydroelectric power with water flowing from Lake Superior. Since 1958 Canada and the United States have regulated Lake Ontario levels to aid navigation, generate hydroelectric power, and protect shore property. Diversions of water into and from the Great Lakes, in addition to the dredging of deeper channels, have also slightly changed the water levels. Appreciation of the international agreements, treaties, judicial decisions, and agencies which now address water level issues on the Great Lakes is necessary to understand how man has tried to control water level fluctuations. For this reason the University study group reported on the institutional aspects of water levels regulation. This analysis includes a chronology of Great Lakes water level regulation, a summary of the IJC's actions with respect to water levels since 1972, relevant legislation and institutional arrangements, Wisconsin's response to the lake levels issue, and a list of governmental agencies interested in lake levels regulation.

During the fall and winter of 1972 Great Lakes Congressmen and President Nixon expressed to the IJC their concern that the September 1955 Modified Rule of 1949 for regulating Lake Superior was contributing to the severe erosion and flooding damages along Lakes Michigan, Huron, and Erie. Initially, the IJC contended that the 1914 Orders of Approval did not authorize the regulation of Lake Superior for the benefit of the lower lakes, but on January 30, 1973, after the United States submitted an "Emergency Application" to alter the Lake Superior regulation plan, the IJC authorized a reduction of outflow from Lake Superior for six months. At the United States' request and with Canada's concurrence, the IJC has indefinitely extended the temporary plan. This action has reduced the levels of the lower lakes while accelerating erosion and flooding damages on Lake Superior. Questions concerning the legality of regulating Lake Superior to benefit the lower lakes and IJC's requirement that those damaged on Lake Superior receive compensation have concerned the States of Minnesota, Wisconsin, and Michigan.

At the request of the Executive Office, the U.S. Army Corps of Engineers has drafted a bill which endorses the concept of regulating Lake Superior for the benefit of the lower lakes. This proposed legislation, which is currently under review by the Office of Management and Budget (OMB) and not publicly available, also addresses the issue of compensating those injured by a new Lake Superior operating rule. Apparently, the bill proposes compensation for losses incurred by hydroelectric power plants on the United States side of the St. Marys River, but indemnification of Lake Superior shore property owners is not certain. Because the projected average annual loss from Plan SO-901 to Lake Superior shore property owners and hydroelectric power companies is approximately only $250,000, the costs of identifying those damages directly attributable to the regulation plan and administering a compensation program may exceed the damages from the new regulation plan (RF Monograph 76-05--Institutions).

On December 9, 1975, U.S. District Court Judge James Doyle ruled that a citizens' suit against the U.S. Army Corps of Engineers for implementing the IJC's January 1973 Emergency Order could be heard before his court. Doyle wrote that if the higher water levels flooded the plantiff's property, "then that land which lies above the normal high water line has been taken within the meaning of the Fifth Amendment."* Similar citizen suits could greatly increase the administrative costs of implementing Plan SO-901, and such costs should be weighed against the Plan's projected benefits.

Because the governments of Canada and the United States asked the IJC to consider only measures within the Great Lakes basin that could reduce the range of lake level stages, the IGLLB did not consider alternative operating policies for the Chicago and Long Lake-Ogoki diversions. Furthermore, the proposed operating plans do not incorporate possible changes in the Lake Ontario operating rule. The Canadian section of the International St. Lawrence River Board of Control is studying the effects of changing the operating criteria on Lake Ontario because the 1958-D operating rule was unable to accommodate the record high supplies of water in 1972 and 1973. The conclusions of the Levels Board may have been different if the IJC had directed it to consider increased discharges from Lake Ontario or variable diversion schemes in Lakes Superior and Michigan.

Other institutions besides the IJC are concerned about Great Lakes water levels. Federal and regional agencies, the Great Lakes states and Province of Ontario, local communities and private organizations have become interested in Great Lakes water levels. The IGLLB was composed almost entirely of federal government personnel--particularly from the Corps of Engineers and the Canadian Department of the Environment, while personnel from the Great Lakes states were not on the Levels Board staff. This lack of state participation has hampered Wisconsin's efforts to evaluate the IGLLB report. The institutions working paper describes not only how the IGLLB was related to other organizations involved with the Great Lakes but also Wisconsin's ongoing effort to integrate lake levels considerations into state environmental policy and its Coastal Zone Management Development Program (CZMDP). Of the many issues which Wisconsin's CZMDP is addressing, lake levels directly affect erosion, flooding,

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* Soucheray et al. v. Corps of Engineers of the U.S. Army et al., _____ F. Supp. _____, (W.D. Wisc. 1975), Opinion and Order 74-C-109, p. 4.

port development, ecologically sensitive areas in the coastal zone, and recreation. The Wisconsin governor's office is relying upon this development program to help determine Wisconsin's position on the regulation of Great Lakes water levels.

# III. SUMMARIES OF PRINCIPAL REGULATION PLANS AND THEIR IMPACT ON LAKES SUPERIOR, MICHIGAN, AND HURON

The Levels Board did not attempt to provide a precise evaluation of the economic benefits or losses of each of the various regulation plans, rather the Levels Board compared the most probable benefits and losses of various plans on a uniform basis and provided a relative indication of the economic effects of various regulation plans. An important consideration, which the Levels Board made for Plan SO-901 but not for other plans, is the range of relative benefits and losses under different possible sequences of net basin supplies. Such a consideration indicates the uncertainty associated with choosing a particular regulation plan. For example, under ten different possible sequences of supplies, the benefits of Plan SO-901 for the entire basin range from $400,000 to $2.7 million. The range of shore benefits and losses is particularly important to Wisconsin because the shore losses on Lake Superior may exceed the shore benefits on Lake Michigan. The ten simulated sequences tested by the Levels Board, for instance, indicate that in four cases the shore losses on Lake Superior equal or exceed the shore benefits on Lakes Michigan and Huron. Because the benefits and losses of a regulation plan appear to be sensitive to the sequence of net basin supplies, even when the long-term mean lake levels remain approximately equal, consideration of the range of benefits associated with each plan is especially important.

## A. Plan SO-901

*Hydrologic Impact.* Relative to the levels produced by the BOC conditions Plan SO-901 reduces the range of stage on Lakes Superior and Michigan-Huron while closely maintaining the long-term mean level of both lakes (Table 1). On Lake Superior the variability of levels (measured by their standard deviation from the mean) increases slightly, partly because the plan increases from 27 to 46 the number of times monthly mean levels exceed 601.4 feet (Table 2). An increase of only 19 months is small for such a long record, but most of these higher levels occur during August-November, a period associated with high damages on Lake Superior. Plan SO-901 and the BOC conditions produce nearly the same number of monthly mean levels above 601.6 feet. Plan SO-901 also tends to increase the levels of that lake during periods of high net basin supplies, such as 1972-1974, and reduce the levels during periods of low net basin supplies (1932-1938).

On Lakes Michigan-Huron Plan SO-901 reduces the maximum levels by 0.43 feet and raises the minimum levels by 0.36 feet, relative to the BOC (Table 1). The smaller variability in levels is due to the reduced frequency of high and low stages (Table 2). On both Lakes Superior and Michigan-Huron Plan SO-901 reduces the frequency of occurrence of levels below the low water datums of 600.0 feet and 576.8 feet (Table 2).

In summary, the differences between lake levels under the BOC regulation plan and Plan SO-901 are relatively modest. A principal reason for the modest effects is the limitation placed upon Lake Superior outflows by the capacity of the St. Marys River and the available storage on downstream lakes. The balancing principle of Plan SO-901 would operate unconstrained only 41% of the time between 1900-1973. The net result of the restrictions on Plan SO-901 leaves climatic influences on net basin supplies as the primary cause of water level problems on Lakes Superior, Michigan and Huron.

*Economic Impacts.* The IGLLB estimates that Plan SO-901 will yield net benefits to the Great Lakesshore property, power, and navigation interests (Table 1) and have a favorable benefit to cost ratio. Because the assumptions and methods used by the Levels Board to evaluate regulation's impact on navigation and shore property probably overstate a plan's benefits, the total expected average annual benefits from SO-901 are likely to be less than $2.3 million.

Wisconsin shore property and navigation interests gain very little from Plan SO-901. The Levels Board analysis of past shore damages indicates that Wisconsin incurred approximately 35% of the average annual damages reported on Lake Superior and 20% of the damages reported along Lake Michigan. If these ratios of past damages remain approximately the same for the incidence of benefits or losses from Plan SO-901, the average annual shore damages on Lake Superior would be $40,000. On Lake Michigan the average annual benefits to Wisconsin shore property would be approximately $90,000.* Although the University analysis of Levels Board data indicates that for Wisconsin the average annual benefits to Lake Michigan riparians outweigh losses to Lake Superior shore property owners, these economic estimates can vary widely such that Lake Superior shore losses may exceed Lake Michigan shore benefits.

As noted earlier in the discussion of the Levels Board's methods of calculating potential navigation benefits, the inclusion of fixed costs in the analysis overstates the future benefits accruing to navigation interests by 33-66%. According to generalized stage-cost curves developed by the IGLLB, Lake Superior shippers experience net losses under SO-901 (RF Monograph 76-02--Navigation).

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* These estimates were made after examining the Levels Board's shore damage data stored with the Chicago District Office of the U.S. Army Corps of Engineers, North Central Division, June 1975.

*Environmental Impact.* The University analysis of the possible impact of Plan SO-901 on wetlands, fisheries, and water quality concludes that this plan probably will not have a major impact on wetlands surrounding Lakes Superior or Michigan. On Lake Superior Plan SO-901 satisfies four of the five criteria for wetland preservation posited by the University study group. Plan SO-901 increases the frequency of high levels on Lake Superior, which could endanger sand spits and bars that protect most of the Great Lakes wetlands, but this plan does not appreciably alter the historical monthly or annual lake level fluctuations. Although SO-901, in contrast to the BOC conditions, raises the long-term minimum levels of both Lake Superior (0.45 feet) and Lake Michigan (0.31 feet), the University analysis concludes that this change would not harm the Great Lakes wetlands. On Lake Michigan Plan SO-901 satisfies all the criteria for wetlands.

On Lake Superior any greater turbidity attributable to increased shore erosion could injure fish which spawn and feed near the shore. The University analysis concurs with the Levels Board's conclusion that the effects on domestic water supplies of increased turbidity from the regulation plan cannot be distinguished from those occurring naturally. Although of only indirect concern for Wisconsin, implementation of SO-901 should include adequate safeguards against extreme minimum flows for the biota of the St. Marys River.

SUMMARY

According to the Levels Board analysis, Plan SO-901 will increase the average annual erosion and flooding damages on Lake Superior by $0.1-2.3 million in comparison with BOC levels. On Lakes Michigan and Huron the Levels Board estimates that Plan SO-901 would reduce shore property damages and increase recreational beach acreage to yield annual benefits of $0.3-1.0 million. The expenses of determining adequate compensation for those injured by SO-901 could offset the plan's potential benefits. The methods used by the Levels Board to estimate the impact of SO-901 on shipping significantly overstates the plan's potential benefits. Plan SO-901 is not likely to degrade the wetlands on either lake unless higher water levels on Lake Superior erode protective sand spits and bars. Increased turbidity from accelerated shore erosion along Lake Superior may have unknown impacts upon fish. The University study group stresses that because of the uncertainty associated with forecasting hydrologic and economic conditions, recognition of the range of possible impacts is more important than assuming that one series of average annual benefits or losses reflects the plan's relative impact on Lakes Superior and Michigan-Huron.

## B. Plans Mod 7 and Mod 8 of SO-901

*Hydrologic Impacts.* Plans Mod 7 and Mod 8 would increase the storage capacity of Lake Superior by lowering the minimum levels of Lake Superior by 0.5 feet and 0.8 feet, respectively, relative to the BOC levels (Table 1). Subsequently, these plans would reduce the long-term range of stage on Lakes Michigan-Huron by more than 1.2 feet (Table 1). Both of these plans increase the variance of Lake Superior levels while reducing the variability of levels on Lakes Michigan and Huron. As Table 2 illustrates the Mod plans reduce the frequency of occurrence of potentially damaging water levels on Lake Superior (above 601.4 feet)

and on Lakes Michigan-Huron (above 579.6 feet). The dramatic increase in the number of times levels would be below 600.0 feet on Lake Superior would require dredging of harbors and channels (Table 2).

Because use of Mods 7 or 8 would not require increasing the channel capacity of the St. Marys River, and because the constraints of the release rule are essentially the same as for the general Plan SO-901, the Mod plans operate unconstrained only 43% or 46% of the time.

*Economic Impact.* Preliminary analyses by the Levels Board using generalized loss curves indicate that, while the average annual benefits to the Great Lakes from Plan SO-901 are approximately $2.1 million, benefits under Plans SO-901 Mod 7 and SO-901 Mod 8 are $6.2 million and $6.0 million, respectively. Because these Mod plans would lower the maximum levels of Lakes Michigan-Huron by 0.2-0.4 feet more than SO-901, less erosion and flooding damage attributable to lake levels would occur on these lakes (Table 1). Whereas under Plan SO-901 the projected average annual erosion and flooding losses on Lake Superior would increase by $0.1 million, Mod 7 and Mod 8 are estimated to reduce these damages by $1.2 million relative to BOC conditions. Although the Levels Board did not specifically evaluate the impact of these plans on recreational beaches, increased beach acreage undoubtedly comprises a large share of these projected benefits.

Under Mod 7 and Mod 8 shipping costs would also be reduced in comparison with the BOC and SO-901 conditions if all harbors and channels in Lake Superior are dredged one foot deeper. The estimated annual average cost of this dredging operation ($3.8 million) considerably reduces the estimated net benefits from either of these plans. Plan SO-901 Mod 7 and Mod 8 would yield small benefits ($0.6-0.9 million) to hydroelectric power interests. The University study group concurs with the Levels Board recommendation that further study of the dredging costs imposed by these plans is necessary before the feasibility of the Mod plans can be determined.

*Environmental Impact.* Because Mods 7 and 8 of Plan SO-901 reduce the long-term range of water levels on Lakes Michigan-Huron, wetlands along these lakes may eventually occupy less area than under BOC or even SO-901 conditions. On Lake Superior the range of lake levels increases by approximately 15-30% in comparison to BOC conditions, and thus the wetlands along Lake Superior eventually may occupy more area. Disposal of dredge spoils (a problem greatly exacerbated by the need for more dredging) will become a greater concern if one of these plans is adopted, because poor siting of disposal fields could harm Lake Superior wetlands and open-lake dumping can increase turbidity.

## C. Plans SEO-42P and SEO-17P

*Hydrologic Impact.* Under Plan SEO-42P and its refined version SEO-17P, Lakes Superior and Michigan-Huron would experience nearly the same variations in mean monthly levels as expected under Plans SO-901. In comparison to SO-901 the SEO plans would lower the long-term mean levels of Lake Michigan and Huron by approximately 0.1 foot and the Lake Superior levels by a trace (Table 1). These similarities between the Plans SEO-17P, SEO-42P, and SO-901 result from the use of the SO-901 operating rule in all three plans.

In comparison with Plan SO-901, Plan SEO-42P produces fewer damaging high water levels on Lakes Superior, Michigan, and Huron. Whereas Plan SO-901 produces 46 months where the mean level of Lake Superior exceeds 601.4 feet, SEO-42P yields 37 occurrences (Table 2). Relative to the BOC levels, Plan SEO-42P produces more levels above the 601.4 level but fewer which exceed 601.5 feet. This reduction in the number of levels above 601.5 feet is a primary reason why the SEO plans are projected to reduce shore damages on Lake Superior.

On Lakes Michigan-Huron the number of times the average monthly water levels fall below the low water datum of 576.8 feet during the 1900-1973 period is 129 for SEO-42P and 137 for SEO-17P, versus 131, 109, 87, and 82 occurrences expected for BOC, SO-901, and its Mods 7 and 8, respectively (Table 2). Thus, the incidence of levels below the low water datum is nearly the same for BOC, SEO-42P, and SEO-17P conditions.

In summary, the SEO plans slightly reduce the long-term mean levels of Lakes Superior, Michigan, and Huron when compared to Plan SO-901. Plans SO-901, SEO-17P, and SEO-42P have virtually the same effects on the range of levels for these three lakes because the SEO plans incorporate the SO-901 operating rule for regulating Lakes Superior and Ontario. The increased discharge capacity from Lake Erie, to be used only during periods of high supplies, reduces the maximum levels on Lake Michigan and also reduces the frequency of extremely high levels on Lake Superior. In comparison to Plan SO-901 and the BOC conditions, SEO-42P slightly increases the likelihood of levels below low water datum (600.0 feet) on Lake Superior. On Lake Michigan SEO-42P increases the chance of levels below low water datum—relative to SO-901.

Under Plan SEO-42P the mean monthly levels of Lakes Michigan-Huron would exceed 579.6 feet thirty times. Comparable occurrences for other plans are Mod 7 and Mod 8 (29), SO-901 (44), and BOC (68) (Table 2). Comparing SEO-42P and SEO-17P to the BOC, the chances of Lake Michigan-Huron levels exceeding 579.0 feet are uniformly lower (Table 3).

TABLE 3 MONTHLY MEAN WATER LEVELS OF LAKES MICHIGAN, HURON, AND SUPERIOR, 1900-1973. NUMBER OF OCCURRENCES ABOVE LEVEL SHOWN

LAKES MICHIGAN-HURON

| Monthly Mean Level (feet) | Basis-of-Comparison (1962) | SEO-42P | SEO-17P |
|---|---|---|---|
| 581.4 | 0 | 0 | 0 |
| 581.0 | 1 | 0 | 0 |
| 580.6 | 6 | 0 | 0 |
| 580.2 | 14 | 7 | 4 |
| 579.8 | 35 | 16 | 13 |
| 579.6 | 68 | 30 | -- |
| 579.4 | 96 | 50 | 40 |
| 579.0 | 195 | 133 | 120 |
| Maximum Level | 581.10 | 580.59 | 580.52 |

LAKE SUPERIOR

| | | | |
|---|---|---|---|
| 602.0 | 0 | 0 | 0 |
| 601.9 | 1 | 2 | 2 |
| 601.8 | 3 | 3 | 2 |
| 601.7 | 9 | 5 | 4 |
| 601.6 | 14 | 11 | 7 |
| 601.5 | 18 | 16 | 12 |
| 601.4 | 27 | 37 | -- |
| Maximum Level | 601.91 | 601.95 | 601.92 |

Source: U.S. Army Corps of Engineers 1974, pp. 10, 13.

Regarding low water levels, the SEO plans would yield from 10 to 30 (5-10%) more months than the BOC or SO-901 where the mean level of Lake Superior falls below 600.0 feet (Table 2).

*Economic Impact.* The U.S. Army Corps of Engineers (1974) estimates the following average annual economic impacts from Plan SEO-17P: $9.8 million reduction in erosion and flooding damages and benefits from increased beach acreage (United States shores only), $300,000 reduction in shipping costs, and $500,000 decrease in hydroelectric power benefits (Table 1). According to the Corps of Engineers' analysis, SEO-17P could reduce erosion and flooding damages along the United States shore of Lake Superior by $300,000. Benefits from increased beach acreage account for approximately one-half ($1,215,000) of the total projected United States shore property benefits along Lake Michigan ($2,503,000). Small losses ($42,000) may occur to marine structures or water intakes due to more extensive dry rot or increased pumping costs. In addition to the annual cost ($72,000) of implementing the SO-901 operating rule at the Lake Superior compensating works, annual expenses for SEO-17P include building the diversion canal through Squaw Island ($460,000).

Although Plans SEO-42P or SEO-17P would yield more benefits to users of Wisconsin's Great Lakes shores than Plan SO-901, the magnitude of these expected returns should be viewed skeptically. Because SEO-42P and similarly SEO-17P are consistently only a few hundredths of a foot lower than SO-901, the benefits indicated for SEO-17P are disproportionately large in comparison to those projected under SO-901 levels. For example, the Levels Board estimates that annual average benefits of $82,000 will accrue to Lake Michigan recreation beaches under Plan SO-901 and $850,000 under SEO-42P, but the difference in mean monthly water levels between these plans never exceeds 0.14 feet. Plan SEO-17P reportedly will yield $1.2 million in average annual benefits from increased beach acreage on Lake Michigan. Although beach acreage will increase under the SEO plans, the University study concludes that the Levels Board overestimated the economic value of this increase. Similarly for Lake Superior the Levels Board projected that Plan SEO-42P increases the average annual shore property benefits by $250,000 over those of Plan SO-901 while the difference in monthly mean levels is at most 0.12 feet.

*Environmental Impact.* The SEO plans probably would not be detrimental to Wisconsin's Great Lakes wetlands. On Lake Superior the effects of Plans SEO-17P and SEO-42P are nearly identical to those of Plan SO-901, but the number of levels exceeding 601.4 feet is reduced. Because the SEO plans lower the expected maximum levels on Lake Michigan, in comparison with Plans SO-901 and BOC conditions, wetlands along this lake would experience less inundation. The impact of the SEO plans upon fisheries will probably be insignificant.

In summary, although Plan SEO-42P yields more months than the BOC where the levels exceed 601.4 feet on Lake Superior, the Levels Board's stage-damage functions indicate a reduction in shore property damages in comparison to the BOC conditions. This anomaly results from the less frequent occurrence of levels between 601.5 to 602.0 feet. For riparian property owners along all the lakes and particularly Lake Erie, the SEO operating concept (with modifications of the 1958-D operating rule for Lake Ontario) is an improvement over the BOC conditions and SO-901 because the maximum levels would be lowered. Before the IJC approves SEO-17P or a later revision, however, the plan should be evaluated against several hydrologic regimes. As noted in the discussion of Plan SO-901, knowledge of the range of possible outcomes is critically important for anticipating a plan's impact upon the Lake Superior shoreline. Naturally, until construction of the Squaw Island diversion channel is completed, Plan SO-901 will be in effect.

# IV. Major Areas which Require Further Research

Both the University working papers and the International Great Lakes Levels Board report point out numerous areas where information is scarce and subsequently where the methods of evaluating the effects of lake level changes are poorly developed. Further research in certain areas is particularly crucial to making appropriate decisions about regulating Great Lakes levels:

- The Levels Board simulated ten possible sequences of supplies which were used to test Plan SO-901. Application of generalized loss curves to each of these sequences presented an indication of the range of benefits which may be achieved under different possible sequences. Because both the range of overall benefits and the distribution of benefits and losses among the various economic interests appear to be sensitive to the sequence of supplies, Plans SO-901 Mod 7 and Mod 8 and particularly SEO-17P should also be tested under a series of possible supply sequences.

- The International Joint Commission has stated that compensation of those damaged will be a necessary component of the proposed regulation plans. The costs of such a compensation program once it is determined, should be included in benefit/cost considerations for selecting an appropriate regulation plan. The Levels Board stated that small net benefits to the Great Lakes would be achieved by instituting a new operating rule which takes into account Lakes Michigan-Huron levels in determining Lake Superior outflow. These benefits could be offset if an expensive compensation program is necessary.

- The climate in the Great Lakes region during the next few decades will probably be cooler and wetter than the first half of the century, and, therefore, the standarized data base used to compare regulation plans should incorporate larger net basin supplies than those represented in the BOC.

- Investigation of the feasibility of regulating diversions in conjunction with the proposed regulation plans should be pursued. A better understanding of the role diversions could have in regulating lake levels would provide a basis for incorporating diversions into regulation plans.

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